TECHNICAL REPORT

Contract Title:	Infrared Algorithm Development for Ocean Observations with EOS/MODIS
Contract:	NAS5-31361
Type of Report:	Semi-annual
Time Period:	July 1993-December 1993
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MODIS INFRARED ALGORITHM DEVELOPMENT

A. Near Term Objectives

A.1. Continue interaction with the MODIS Instrument Team through meetings and electronic communications.

A.2 Continue algorithmic development efforts based on experimental match-up databases and radiative transfer models.

A.3 Continue evaluation of different approaches for global SST data assimilation and work on statistically based objective analysis approaches.

A.4 Continue evaluation of high-speed network interconnection technologies with preliminary foci on ATM and LEC toll options.

A.5 Provide investigator and staff support for the preceding items.

B. Overview of Current Progress

B.1 June-December 1993

Activities during the last six months have continued on the previously initiated tasks and have been enhanced with the initiation of several new tasks. New work is going on in the areas of understanding the impact of the diurnal cycle; the skin temperature vs. the analysis product methodology; validation of a new suite of algorithms with the 1988 Pathfinder dataset; preliminary discussions on IR algorithm development and calibration/validation as part of the MODIS Ocean Science Team cruises; and work on implementation of a design for a wide area network based on ATM technology. Previously initiated activities, such as additional definition of the ATVD data volumes and other team related activities, are ongoing.

B.1.1 Diurnal Cycle of Sea Surface Temperature

Current satellite data products in the U.S. which produce sea surface temperature fields are based on the NOAA/AVHRR polar orbiting, multi-wavelength instrument. This program overflies the ocean four times a day; roughly 02, 07, 14 and 19 local sun time. It has been known for quite a while that the diurnal effects on skin temperature of the ocean can have amplitudes ranging from .03C to potentially as much as 1.5C and that these offsets can vary substantially from the bulk temperature as a function of solar insolation, wind stress and humidity. Since the MODIS instrument will have a different pass time than the current constellation of NOAA polar orbiters, it was expected that this might be a source of bias between EOS/MODIS derived sea surface temperature estimates and estimates made by spacecraft such as NOAA, which viewed the ocean at different local sun times. It is very difficult to test this hypothesis with current space borne radiometers since there is a paucity of data at different daytime solar illuminations. It has long been known that the nighttime SST estimates could differ substantially from daytime SST estimates for the NOAA polar orbiters.

As it happens, the longitude of the ascending node relative to the local sun time for some of the NOAA satellites, *e.g.*, NOAA-9, has drifted substantially over a given mission. In the case of NOAA-9, this drift has amounted to several hours over four years. This drift gives us an opportunity to start examining the impact of varying pass time on the mean retrieved SST. Figure 1 presents a plot of the mean pass time as a function of time and orbit for NOAA 9.

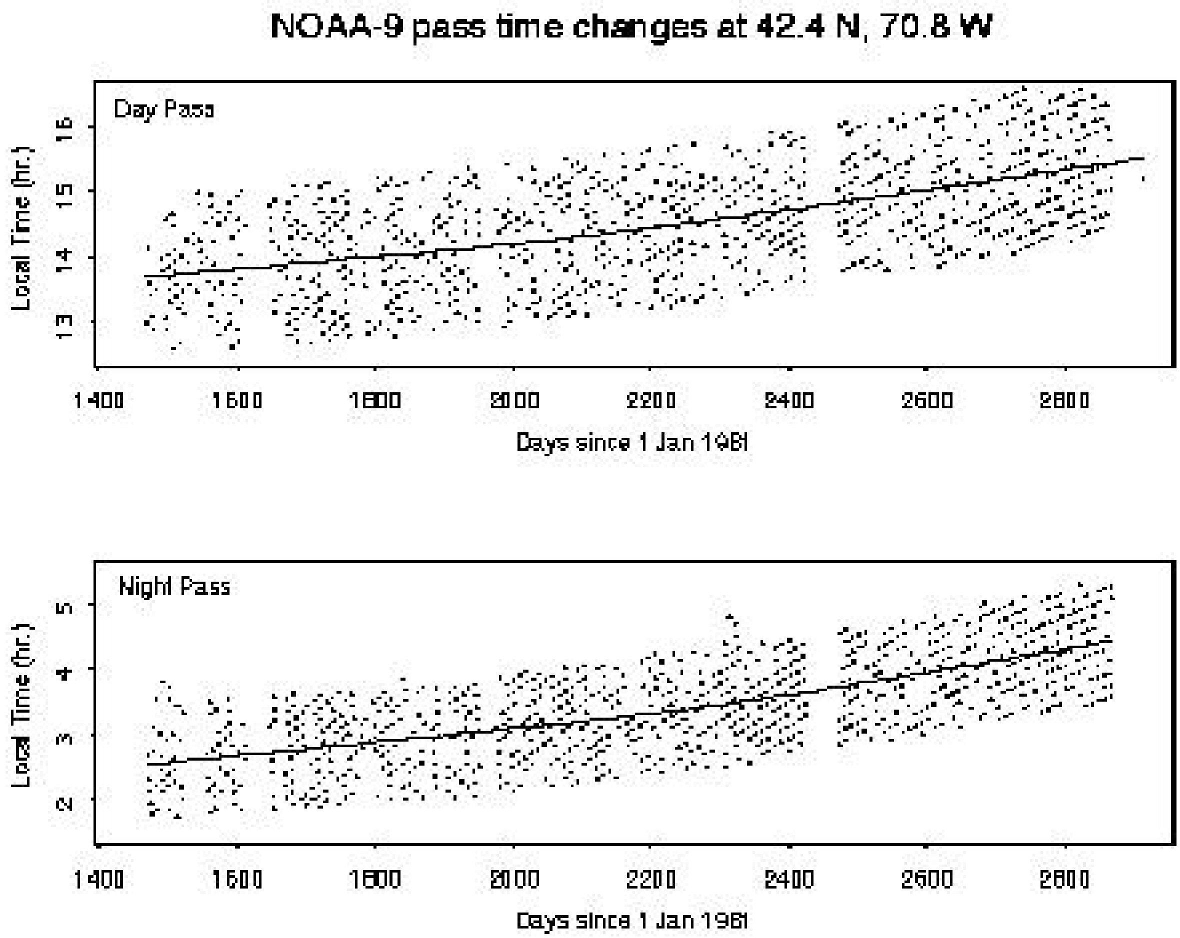

Fig. 1. Change in local sun time of NOAA-9 pass for a buoy located at 42.4°N, 70.8W. The spread is caused by the location being in view of multiple passes. The panels are for day (top) and night (bottom).

One can see that the progression is fairly linear in time, with a change of ~2 hours in 4 years. However, if one reviews the diurnal cycle of SST, *e.g.*, Dickey *et al.* (1991), it is apparent that the diurnal cycle is not a simple linear function of the local sun time, but has a nonlinear behavior which is location and time dependent. Thus, it is not straightforward to quantify the impact of changes in local sun time on the retrieved SST field; however, qualitatively the following can be said: for an afternoon orbit (13/14 local sun time) we would expect a drift to later times of the equatorial crossing in the afternoon to increase the mean SST until one is far enough away from the time of maximum heating, such that the ocean surface starts cooling. In the case of the evening (19 LST) pass, one would expect to either see small change as a function of later pass times or diminution of the mean SST with the onset of nighttime conditions.

Figure 2 shows an example of residuals from a particular algorithm for NOAA 9 as a function of time. You will note that for daytime (14 LST) retrievals, these residuals are gradually increasing at low temperatures as might be expected from the qualitative analysis, however, the warmer temperature ranges (>15C) show the opposite behavior.

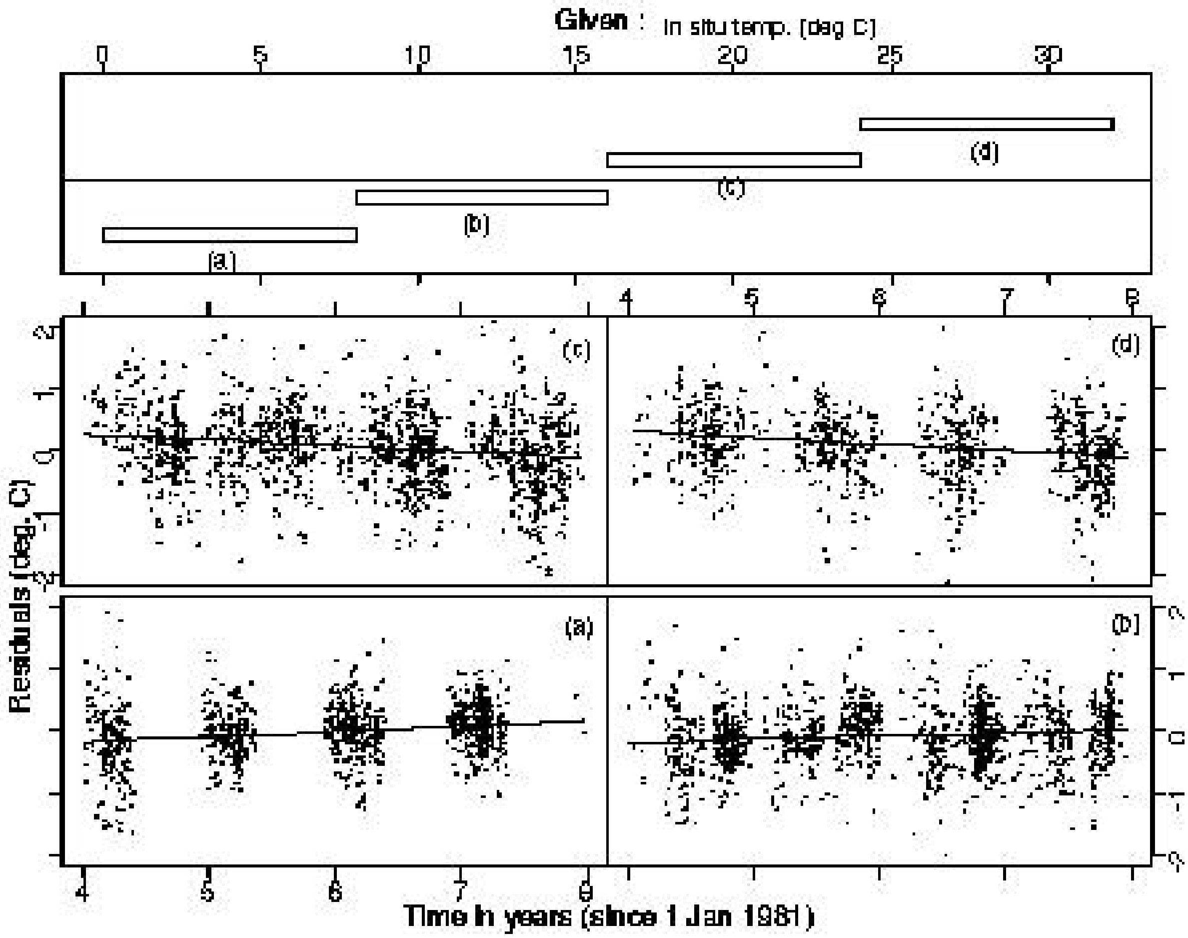

Fig. 2. Co-plots of residuals from the east coast *match-up* database where *in situ* temperature is segmented into four ranges (see top panel) and the temporal dependence is explored. The lines represent *loess* fits to each series.

Since ocean surface heating will be a strong function of wind, latitude and season, it is unclear whether one can quantitatively correct for this effect. It does seem reasonable, however, to continue analysis in this area in order to derive appropriate analysis criteria for compositing the various MODIS and/or other satellite derived retrievals into a single analysis.

B.1.2 Algorithm Development Efforts Based on Experimental Match-up Data bases

Work has continued and good progress has been made in terms of evaluating a hierarchy of algorithms for atmospheric correction of the infrared retrievals. The lowest order algorithm in the hierarchy is one based on the McClain MCSST formulation. This was taken as a base to test all other implementations. Two implementations have been extensively studied, one based on the work of Walton (NLSST) and the other a variation on the NLSST approach where a piece wise set was used for correction (Evans/NLSST).

It is apparent from the analyses that algorithms which are linearized above the current mean mesoscale temperature perform significantly better than approached which have no current or near past knowledge of the local SST. RMS performance of the NLSST type approaches is anywhere from 10 to 25% better with RMS errors 0.1 to 0.1C lower than for MCSST type algorithms.

The current state-of-the-art for AVHRR observations, as determined from the match-up database, gives RMS values of approximately 0.5C based on global monthly composite datasets. It is not difficult to maintain this level of error with biases of order ± 0.1C on an annual basis. However, to reduce interannual changes, other approaches which are sensitive to pass time (as noted in the first section) must be employed.

The major limitations in the AVHRR system seem to involve three main issues: (1) basic instrumental calibration, (2) the NEΔT of the instrument, and (3) the impact of water vapor on the opacity of the 10/11 μ windows for tropical atmosphere. Parenthetically it should be noted that MODIS offers significant improvements in all of these areas and, thus, there is a reasonable opportunity to reduce the RMS errors to the 0.4C level as is stated in the ATBD.

B.1.3 ATBD

There has been limited work in the last quarter in the ATBD. Principal focus has been on improving the definition of the match-up database characteristics and on defining networking needs for post launch calibration/validation activities. The data estimates given in the ATBD seem to be reasonable, given the assumptions. A way to significantly impact the data flow needs would be to identify a two-dimensional format which would permit significant comparison of redundant information; *e.g.*, long term, *etc*.

B.1.4 OPHIR Instrument Utilization

Extensive discussions are ongoing with Dr. S. Hooker (SeaWiFS Project) and Dr. W. Esaias (SeaWiFS Project Scientists and MODIS Ocean Team Leader) concerning the most appropriate strategy for infrared observations on the MODIS Ocean Science Team pre-launch and post-launch cruises.

The Principal Investigator has support in his budget (over the next several years) to acquire several infrared radiometers to be placed on these cruises and to collect data for algorithm development. Goals of the algorithm development focus on better understanding radiometric *vs.* bulk temperatures in a variety of sea conditions and expansion of high quality match-up observations.

GSFC, through SBIR support, has acquired a prototype radiometer from OPHIR which appears to be appropriate for MODIS efforts. Since it is a prototype and was acquired through the SBIR process, it has several aspects which must be addressed before it will really fulfill our requirements. They are principally in two areas: (1) instrument characterization, and (2) procedures and hardware for field deployment.

We will propose to the MODIS Team Leader that the team consider institution of an *IR instrument round robin*, modeled on the SeaWiFS Project's *visible round robin*. The purpose of this round robin would be to develop characterizations of the various instruments used for *in situ* radiometric temperature estimation and, in particular, to provide a good inter calibration of the various devices. From our perspective it seems that this should be a MODIS-based initiative and, in fact, might be of broader interest to other EOS teams besides MODIS. In any event, our proposal will be to have the round robin run from Goddard, most likely through the MODIS Calibration Team activities.

To address the second area of concern, in an exchange of e-mail with W. Esaias, we have agreed to a process whereby W. Emery from U. Colorado would use the OPHIR instrument over the next six months and provide field operating procedures and information needed to effect data acquisition and quality assessment. The instrument would then be integrated with the visible instrumentation (D. Clark/S. Hooker) being deployed for MODIS and SeaWiFS algorithm development activities.

To accelerate the latter activity, we (Evans and Brown) are providing computer programming and systems design support to the MODIS ocean cruise efforts and will continue to do so in order to effectively integrate the surface optical infrared and environmental measurements.

B.1.5 Wide Area Networking

Efforts continue to demonstrate experimental wide area high speed network between the University of Miami, Oregon State University and the Naval Research Laboratory. ATM switches have been ordered for each site (through non-EOS funding) and installation is expected in late January or early February. Advanced discussions are ongoing with NRL/DOD, the two universities, and MCI, to install a 45 Mb (DS-3) network between the three sites and have it operational by mid to late February.

Currently the following experiments are planned:

(1) Model visualization and data assimilation at Oregon State (on the OSU CM-5);
(2) Provision of near real time infrared and ocean color observations from AVHRR and SeaWiFS systems to OSU for data assimilation from Miami;
(3) Integration of near real time buoy and tower data (via NRL) with satellite data (Miami) and model data (OSU);
(4) Visualization of combined data sets and analysis in near real time of model *vs.* satellite *vs. in situ* observations.

Preliminary results of this activity are expected by late fall.

C. Investigator Support

October	G. Halliwell
	G. Goni
November	G. Goni
	A. Kroger
	S. Walsh
December	J. Brown
	G. Goni
	A. Kroger
	S. Walsh

D. Future Activities

D.1 Current

D.1.1 Algorithms

a. Continue to develop and test algorithms on global retrievals.
b. Evaluation of global data assimilation statistics for SST
c. Configure and utilize various AFCRL transmission codes

d. Revision of the ATBD
e. Implement ATM based network test bed
f. Continued integration of new 100 Specmark+ workstations into algorithm development environment

D.1.2 Investigator support
Continue current efforts

E. Problems

No new problems to report.

References:

T.D. Dickey. The emergence of concurrent high-resolution physical and bio-optical measurements in the upper ocean and their applications. **Rev. Geophys. 29**(3), 1991: 383-413.